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Can plantations develop understory biological and physical attributes of naturally regenerated forests?

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ABSTRACT

With an increasing proportion of natural forests being replaced by plantations, there is a need to determine their potential to fulfill ecological purposes other than wood production. This study evaluated the extent to which deciduous and coniferous plantations develop understory attributes comparable to those of naturally regenerated stands. A functional group approach was used to synthesise species responses in terms of their ecological traits. Multivariate analyses of ecological traits revealed 16 emergent groups that shared common traits associated with a similar life history strategy. Responses of these groups, understory structure, and understory environmental conditions to plantation types and stand stages were analyzed and compared to naturally regenerated stands. Clear associations of trait responses to stand developmental stages and plantation types emerged. Light-demanding and wind-dispersed species groups were associated with early-successional stages, while woody groups, ferns and ant-dispersed spring-flowering herbs were associated with late-successional stages. Analyses also revealed an indicator group associated with old naturally regenerated forest. The understory functional groups and environmental conditions of deciduous plantations converged toward those of old naturally regenerated forests. However, understory structure in deciduous plantations remained poorly developed and richness of the indicator group was low compared to unplanted stands. Conifer plantations, currently the most common plantation type in the northern hardwood biome, showed a completely different pathway of understory development. Modifications to current plantation management practices are proposed to help recreate or maintain natural understory biological and physical attributes.

1. Introduction

Around 60,000 km^2 of primary forest are lost or modified annually by human interventions around the globe (FAO, 2007). In many regions, this marked loss of natural forests has been offset by the rapid increase in forested lands allocated to plantations (FAO, 2007). While plantations provide tree cover and forest wood products, little is known about their potential to fulfill other ecological services typical of the ecosystems that they are replacing, such as the maintenance of biodiversity. The question has arisen therefore whether plantations can develop ecological attributes similar to naturally regenerated forest ecosystems over time.

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Conceptually, natural forests are complex adaptive systems dominated by native tree species that regenerate themselves naturally. They are composed of myriads of living organisms together with their abiotic environment, and are not subject to agricultural practices (Gardner-Outlaw and Engelman, 1999; Kimmins, 1997). Such forests exhibit connectivity among their components, are dynamic, and are self-organized into hierarchies and cycles (Levin, 1998; Holling, 2001). Their complexity is expressed at three levels of diversity: compositional, structural and functional (Noss, 1990).

In contrast to naturally regenerated forests, plantations are generally composed of one or several artificially established tree species, whose individuals are even-aged and regularly spaced (FAO, 2007). Many plantations are also made of genetically improved native tree species or fast-growing exotic species. They are typically managed on a relatively short rotation, which contrasts sharply with the longevity that characterizes natural forest components. From the perspective of wood production, plantations have been very successful, producing roughly half of the world wood products on less than 5% of the world's forest cover (FAO, 2007). However, with the increasing conversion of primary forests (i.e. natural forests never disturbed directly by human), and modified natural forests (i.e. managed forests that regenerate naturally; FAO, 2007) to plantations worldwide, the question has arisen as to what extent plantations that are managed for timber production can also provide some of the basic ecological attributes found in more natural forests, particularly the conservation of biodiversity (Evans, 1999; Kanowski et al., 2005; Stephens and Wagner, 2007).

At the same time, modernization of agriculture of the last century resulted in the abandonment of many agricultural lands. While natural revegetation often occurs rapidly on these lands, the resulting understory communities are generally considered as biologically impoverished relative to the original forest because of their (i) altered composition and poor richness of species with high conservation value (Flinn and Vellend, 2005; Singleton et al., 2001), and (ii) low forestry potential (Benjamin et al., 2006; D'Orangeville et al., 2008). In part because of negative societal perceptions of abandoned farmlands (Benjamin et al., 2007; Hunziker, 1995), these lands are often converted into agricultural fields or into plantations by rapid afforestation. Abandoned agricultural lands being a transitional stage, vegetation development greatly varies in time and space, from herb-dominated communities to communities dominated by shrubs and pioneer trees (Benjamin et al., 2005; Flinn and Vellend, 2005). Abandoned agricultural lands also vary according to their land use history, with succession on former pasturelands being quite different than that on cultivated fields or hay meadows (Benjamin et al., 2005; Flinn and Vellend, 2005; Stover and Marks, 1998). Among abandoned agricultural lands with various land use histories, pasturelands that have not experienced modern heavy machinery plowing hold particular potential for natural revegetation. This potential arises in part because they have preserved some of their original micro-topography and soil properties (Beatty, 2003) and may possess relict populations of forest herbs (Stover and Marks, 1998).

To address the question of the capacity of plantation to provide the basic ecological attributes of forest, one has to first determine what makes a forest a fully self-sustaining and functional ecosystem. This has remained difficult to define due to the intrinsic spatial and temporal complexity of such ecosystems. Consequently, ecologists have sought to develop integrative tools that can take into account the complexity of forest ecosystems without having to put all of the pieces of the puzzle together. The ecological integrity concept, which can be defined broadly as the capability of an ecosystem to maintain a community comparable to that of a natural habitat for a given region (Karr and Dudley, 1981), provides a valuable framework for evaluating heavily modified systems such as plantations.

This study aimed at evaluating to what extent plantations can be compared to naturally established forests. To characterize the functionality of forest ecosystems, we used understory community development, in terms of its functional and structural attributes, as an indicator of the ecological integrity of the whole ecosystem. The understory flora is a suitable key element to evaluate ecological integrity of an ecosystem because of its high compositional, structural and functional diversity, its numerous interactions with different trophic levels, and its important role in ecosystem functioning (George and Bazzaz, 2003; Gilliam and Roberts, 2003; Nilsson and Wardle, 2005).

A plant functional type (PFT) approach was used in order to obtain a more synthetic view of the understory community, which was free of differences found at the species level (Lavorel et al., 1997). Based on universal vegetation traits rather than on site-specific vegetational composition, the PFT approach has been shown to greatly facilitate large scale studies or inter-regional comparisons (Cramer, 1997; Graae and Sunde, 2000; Aubin et al., 2007) and has been frequently used for the characterization of vegetation responses to human-induced change (e.g. Verheyen et al., 2003).

We compared assemblages of understory species in conifer and deciduous plantations established in the northern hardwood biome of eastern Canada. Until recently, plantations in temperate deciduous regions of Europe and North America were almost exclusively composed of monospecific conifer stands. Deciduous plantations have been slowly gaining in popularity but they are still marginal (Cogliastro et al., 2006), representing less than 10% of the planted trees in the deciduous zone of Quebec (MRNFP, 2006). Except for studies dealing with vegetation competition, very few studies have been conducted on understory development in North American plantations. Most studies on North American understory flora in plantations have been conducted in boreal forests and only account for conifer plantations (Swindel and Grosenbaugh, 1988; Ramovs and Roberts, 2005; Newmaster et al., 2006; Gachet et al., 2007). These studies observed a generally low abundance and diversity of native forest herbs in plantations. In Europe, Herault et al. (2005) compared understories of Norway spruce plantations with those of natural deciduous forests and found that, functionally, conifer plantations' understories were completely different from natural deciduous stands. To our knowledge, studies from the temperate deciduous region of North America have neither characterized the understory development of coniferous plantations nor compared them with those of deciduous plantations.